

NASA's Physics of the Cosmos Program

Brian Williams
Interim PCOS Chief Scientist

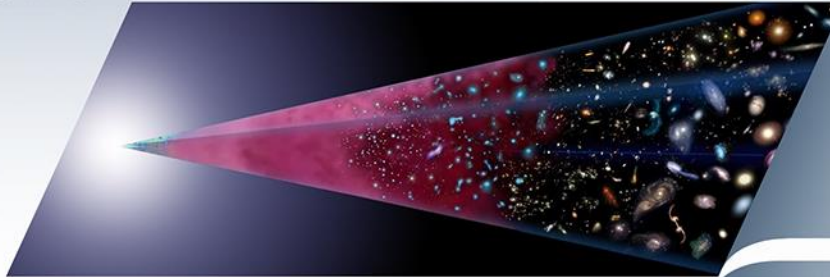
AAS
11 Jan 2021

Why Astrophysics?

Astrophysics is humankind's scientific endeavor to understand the universe and our place in it.



How did our universe begin and evolve?



Physics of the Cosmos (PCOS)



How did galaxies, stars, and planets come to be?



Cosmic Origins (COR)



Are we alone?



Exoplanet Exploration (ExEP)

Program Office Themes

Enduring National Strategic Drivers



1972



1982



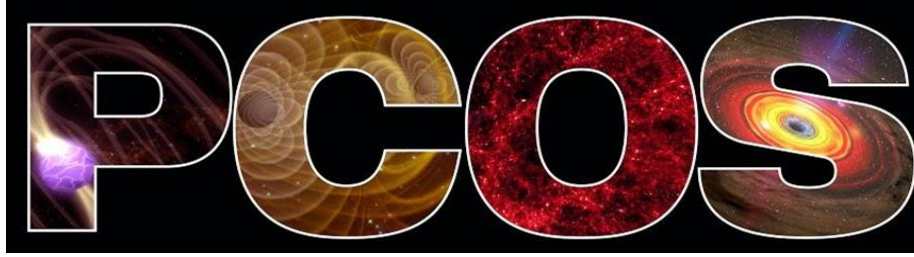
1991



2001



2010



Physics of the Cosmos Program Office Purpose:

to explore some of the most fundamental questions regarding the physical forces and laws of the universe:

- the validity of Einstein's General Theory of Relativity and the nature of spacetime;
- the behavior of matter and energy in extreme environments;
- the cosmological parameters governing inflation and the evolution of the universe; and
- the nature of dark matter and dark energy.

Physics of the Cosmos spans the fields of high-energy astrophysics, cosmology, and fundamental physics, with a wide range of science goals. These include the following:

- General Relativity and the Nature of Spacetime
- Massive Black Holes and the Evolution of Galaxies
- Matter and Energy in the Most Extreme Environments
- Dark Energy
- Big Bang and the Evolution of the Universe

More resources: <https://pcos.gsfc.nasa.gov>



Physics of the Cosmos

[About PCOS](#)[PhysPAG](#)[Mission Studies](#)[Technology](#)[PCOS News Archive](#)

Physics of the Cosmos Science

Physics of the Cosmos spans the fields of high-energy astrophysics, cosmology, and fundamental physics, and includes a wide range of science goals. These include the following:

Dark Energy

The discovery that the expansion of space is accelerating presents one of the most important scientific problems of our time. The implication that the universe is dominated by an unknown entity, now called "dark energy," that counters the attractive force of gravity, may revolutionize our understanding of cosmology and fundamental physics.

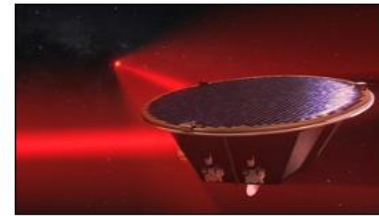
Read more [Expand our knowledge of dark energy](#)

Big Bang and the Evolution of the Universe

The cosmic microwave background (CMB) originated just 380,000 years after the Big Bang, when the Universe was dense, hot, and opaque. As the Universe cooled, the light was decoupled and escape from the matter. We observe that same light today, stretched by the expansion of the universe to a cold 2.7K glow. Observations of the CMB have driven our understanding of the early Universe, and are one of the few probes of the inflationary epoch.

Read more [Precisely measure the cosmological parameters governing the evolution of the universe and test the inflation hypothesis of the Big Bang](#)

General Relativity and the Nature of Spacetime



PCOS News

Program News and Announcements

16 December 2020

The 237th Meeting of the American Astronomical Society, Virtually Anywhere, 11–15 January 2021, will include Physics of the Cosmos events. The PCOS AAS2021 Meeting page lists currently scheduled sessions, presentations, chats, and displays » [Details](#).

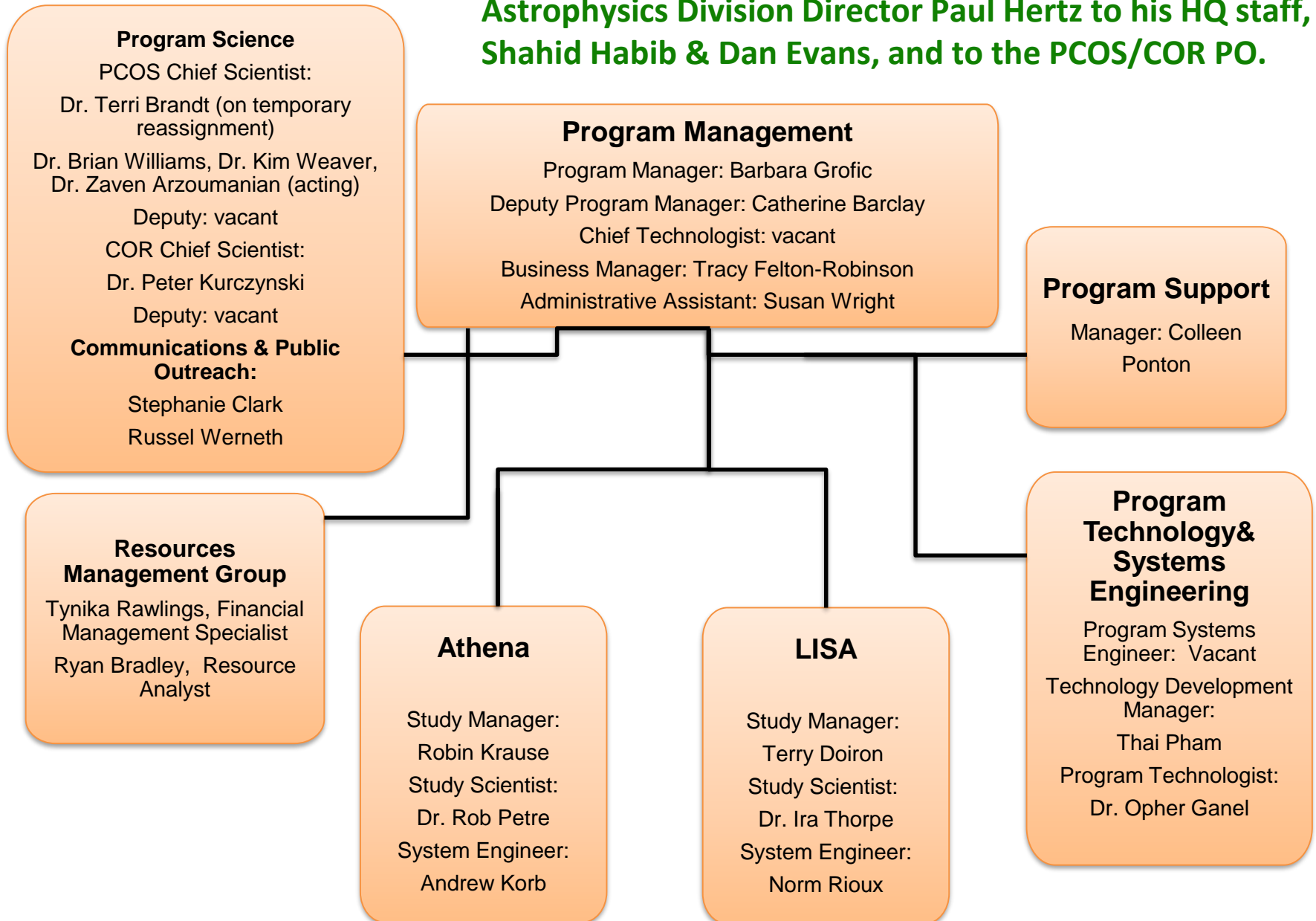
4 December 2020

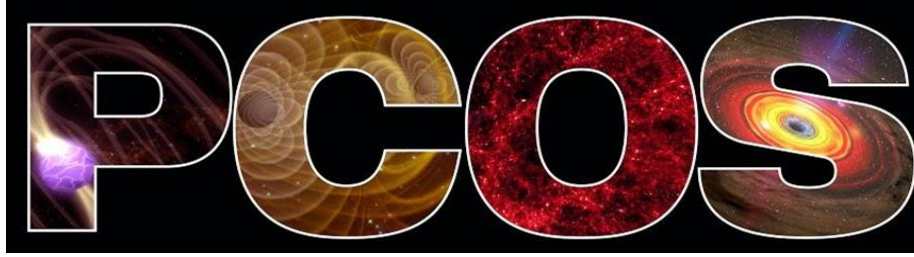
Payloads and Research Investigations on the Surface of the Moon (PRISM) Step-2 Due Date. Step-2 proposals now due **3 February 2021**. Step-1 proposal due date unchanged as **11 December 2020** » [Details](#).

4 December 2020

Release of Final text and Due Dates for ROSES Post-COVID Recovery program. Requests received by **4 January 2021** will be

**PCOS/COR Program Office (PO) authority flows from
Astrophysics Division Director Paul Hertz to his HQ staff,
Shahid Habib & Dan Evans, and to the PCOS/COR PO.**





Activities supporting PCOS goals and priorities:

- Managed by the PCOS/COR Program Office at NASA's Goddard Space Flight Center and reported to NASA Headquarters.
- Include:
 - **Mission studies** and pre-project mission oversight, insight, and support
 - **Strategic technology** (SAT) maturation oversight, insight, and support
 - **Community engagement**, including via the Physics of the Cosmos Program Analysis Group (PhysPAG)
- Maintaining **science cognizance** to enable more successful NASA strategic planning

The PCOS Program Office hosts

- ATHENA Study Office
- LISA Study Office

and oversees

- science and
- technology activities

for NASA's contribution to these ESA-led and other strategic missions.

Athena

Athena is an ESA flagship X-ray mission slated for launch in the early 2030s

Two instruments provided by member states:

- calorimeter (X-IFU) and
- wide-field imager (WFI)

NASA is planning hardware contributions, with options for both X-IFU and WFI, and is discussing observatory contributions.

Current status: in (ESA) Phase B

- Nov 2019: Athena passed Mission Formulation Review (MFR)!
- Mission Adoption Review scheduled for June 2022
- US Athena Study will become a Project in May 2022

NASA Athena Science Team is co-chaired by Jon Miller (Michigan) and Laura Brenneman (SAO)



For more info:

<http://www.the-athena-x-ray-observatory.eu/>

<https://asd.gsfc.nasa.gov/athena/>

LISA



LISA is an ESA-led space gravitational wave observatory.

NASA is a junior partner with possible technology contributions, including:

- Laser (GSFC, JPL)
- Telescope (GSFC, U. Florida)
- Charge management system (U. Florida)

Additional NASA contributions will include

- Science Ground System Support
- Precursor Science programs
- Guest Investigator programs

Current status: in (ESA) Extended Phase A

- Dec 2019: LISA passed ESA Mission Consolidation Review
- Mission Formulation Review in Fall 2021
- Mission Adoption currently anticipated in mid-2020s.

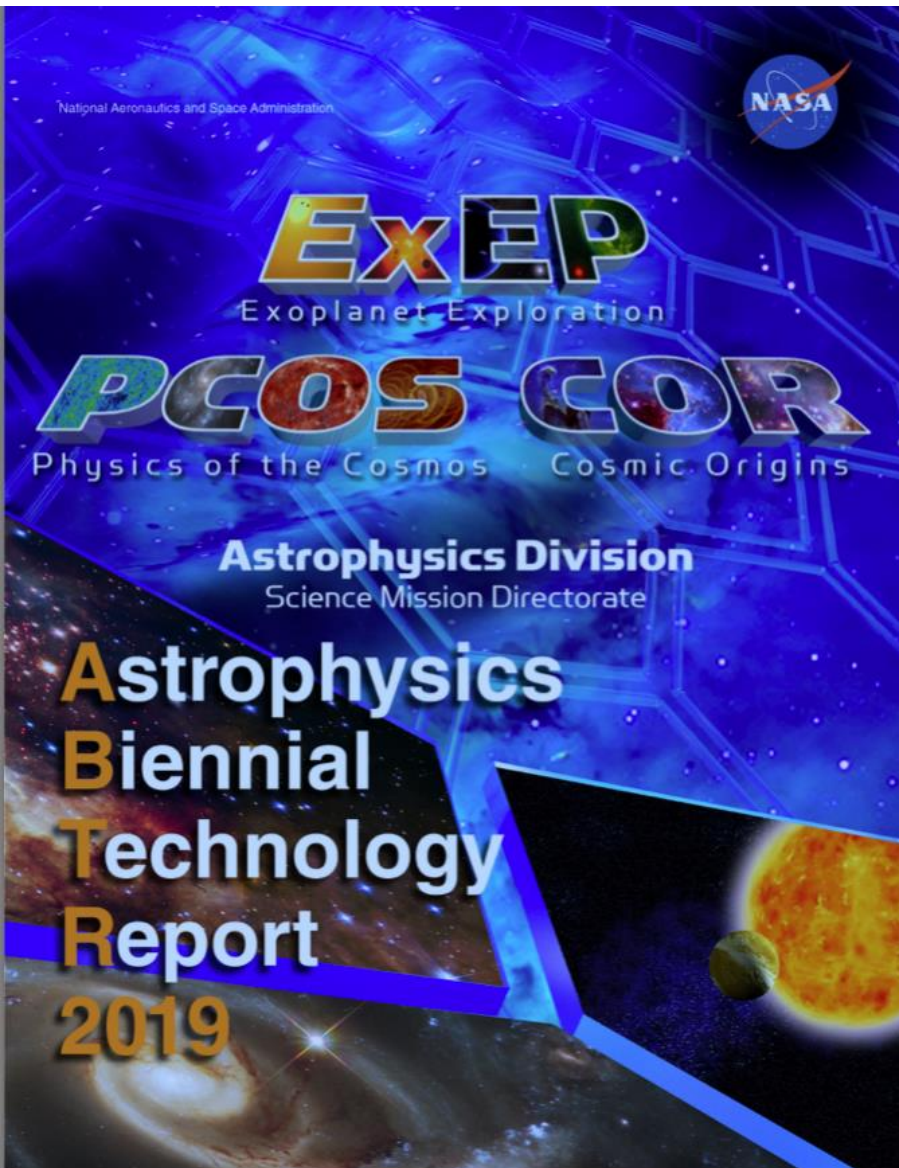
NASA LISA Study Team (Kelly Holley-Bockelmann, Chair) highlights:

- Science Support Taskforce Report: Maximizing US Participation in LISA Science

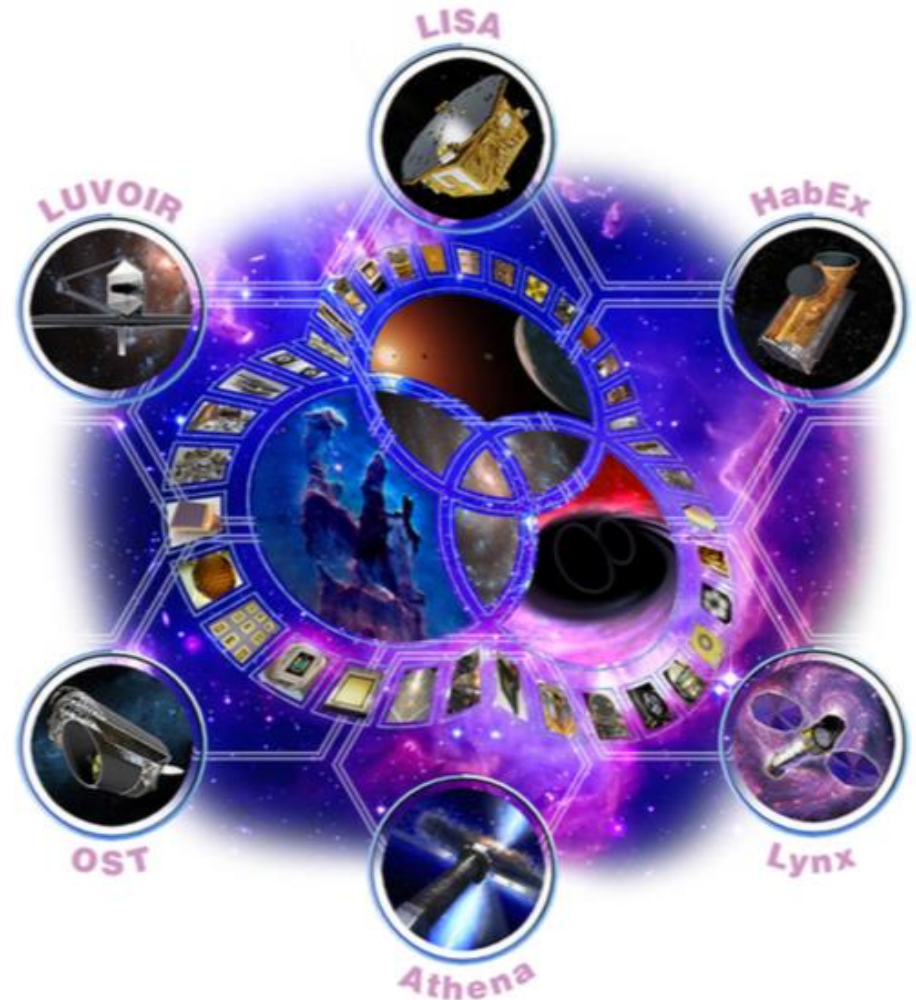
For more info:

<https://sci.esa.int/web/lisa/> and <https://lisa.nasa.gov/>

First Astrophysics Biennial Technology Report

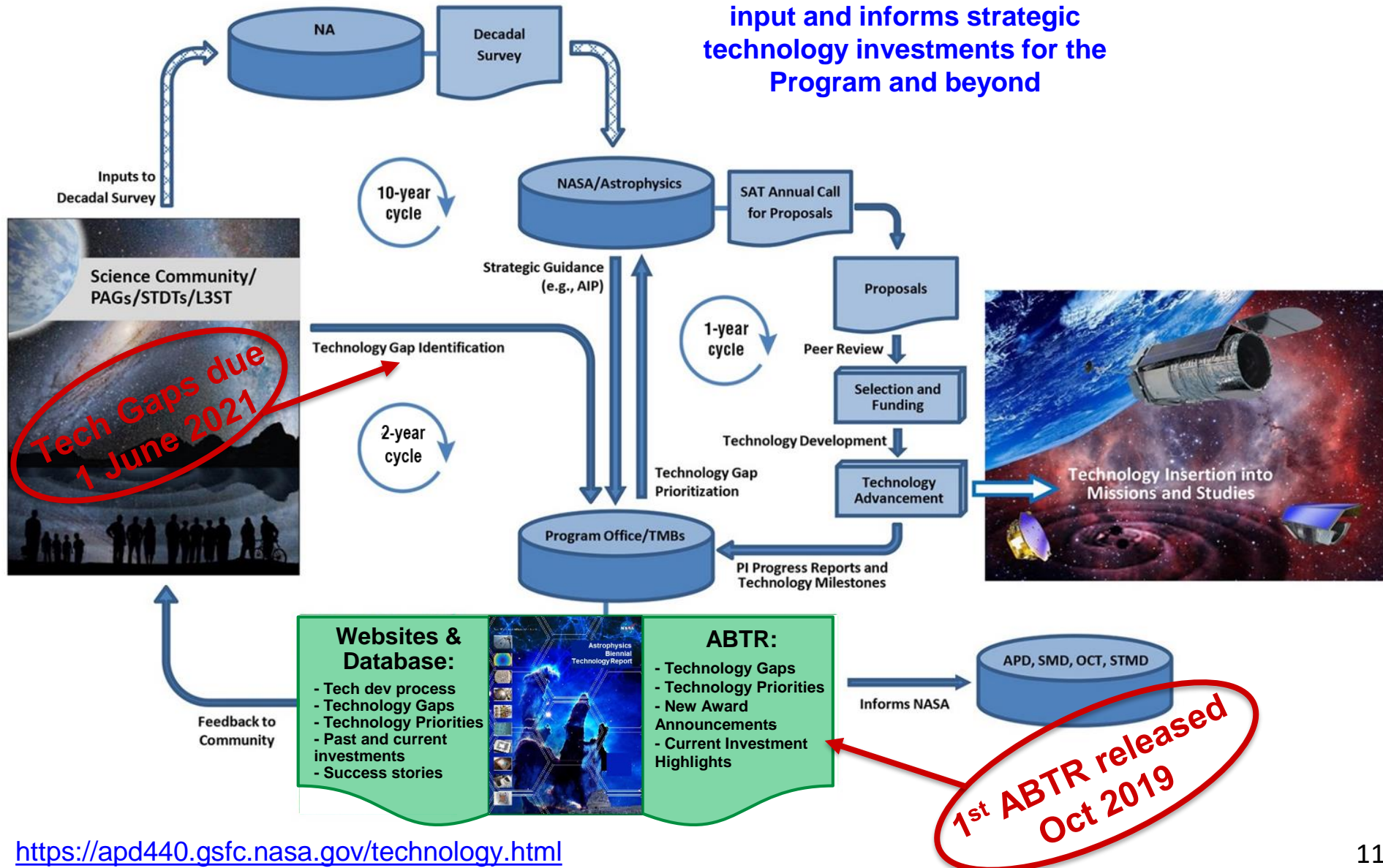


Process is responsive to community input and informs strategic technology investments for the Program and beyond



Strategic Technology Development Process

Process is responsive to community input and informs strategic technology investments for the Program and beyond



Technology Gap Solicitation



Astrophysics Technology Development

About

Techn



Technology Gaps



Technology Database



Program Benefits

Technology Gap Form

The Program Office solicits community input on gaps between the current state of the art and technology needed for the strategic missions of the coming decades to achieve science goals. The next prioritization will take place in 2021.

Download the Astrophysics Techn
to submit your entry by Jun

ABTR: Tech Gaps

Tier 1 Technology Gaps

Angular Resolution (UV/Vis/NIR)

Coronagraph Contrast

Coronagraph Contrast Stability

Cryogenic Readouts for Large-Format Far-IR Detectors

Fast, Low-Noise, Megapixel X-Ray Imaging Arrays with Moderate Spectral Resolution

High-Efficiency X-Ray Grating Arrays for High-Resolution Spectroscopy

High-Resolution, Large-Area, Lightweight X-Ray Optics

Large-Format, High-Resolution, UV/Vis Focal Plane Arrays

Large-Format, High-Spectral-Resolution, Small-Pixel X-Ray Focal-Plane Arrays

Large-Format, Low-Noise and Ultralow-Noise Far-IR Direct Detectors

Large-Format, Low-Noise, High-QE Far-UV Detectors

Next-Generation, Large-Format, Object Selection Technology for Multi-Object Spectrometers for LUVOIR

Vis/NIR Detection Sensitivity

ABTR: Tech Gaps

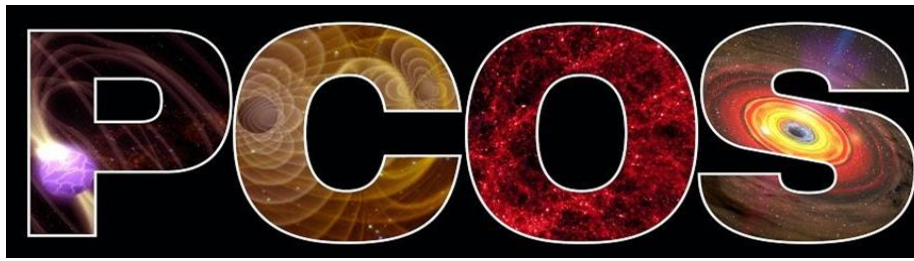
Tier 1 Technology Gaps	
Angular Resolution (UV/Vis/NIR)	
Coronagraph	Tier 2 Technology Gaps
Coronagraph	Advanced Millimeter-Wave Focal-Plane Arrays for CMB Polarimetry
Cryogenic Re	Detection Stability in Mid-IR
Fast, Low-Noise	Heterodyne FIR Detector Arrays and Related Technologies
Spectral Reso	High-Efficiency Object Selection Technology for UV Multi-Object Spectrometers
High-Efficiency	High-Performance Spectral Dispersion Component/Device
High-Resolution	High-Reflectivity Broadband FUV-to-NIR Mirror Coatings
Large-Format	High-Throughput Bandpass Selection for UV/Vis
Large-Format	Large-Format Object Selection Technology for Multi-Object
Large-Format	Spectrometers for HabEx
Large-Format	Starshade Deployment and Shape Stability
Next-Generation	Starshade Starlight Suppression and Model Validation
Spectrometers	Stellar Reflex Motion Sensitivity – Astrometry
Vis/NIR Detec	Stellar Reflex Motion Sensitivity – Extreme Precision Radial Velocity

ABTR: Tech Gaps

Tier 1 Technology Gaps		
Angular Resolution (UV/Vis/NIR)		
Coronagraph	Tier 2 Technology Gaps	
Coronagraph	Advanced Millimeter-Wave Focal-Plane Arrays for CMB Polarimetry	
Cryogenic Re	Detection Stabil	Tier 3 Technology Gaps
Fast, Low-Noise	Heterodyne FIR	Advanced Cryocoolers
Spectral Reso	High-Efficiency	High-Performance, Sub-Kelvin Coolers
High-Efficiency	High-Performance	Large Cryogenic Optics for the Mid-IR to Far-IR
High-Resolution	High-Reflectivity	Long-Wavelength-Blocking Filters for X-Ray Micro-Calorimeters
Large-Format	High-Throughput	Low-Noise, High-QE UV Detectors
Large-Format	Large-Format O	Low-Stress, Highly Stable X-Ray Reflective Coatings
Large-Format	Spectrometers f	Photon-Counting, Large-Format UV Detectors
Large-Format	Starshade Depl	Polarization-Preserving Millimeter-Wave Optical Elements
Next-Generati	Starshade Starli	UV Coatings
Spectrometers	Stellar Reflex M	UV Detection Sensitivity
Vis/NIR Detec	Stellar Reflex M	UV/Vis/NIR Tunable Narrow-Band Imaging Capability
		Warm Readout Electronics for Large-Format Far-IR Detectors

ABTR: Tech Gaps

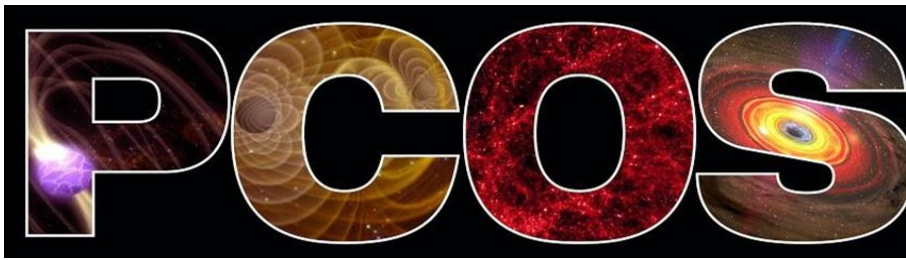
Tier 1 Technology Gaps			
Angular Resolution (UV/Vis/NIR)			
Coronagraph	Tier 2 Technology Gaps		
Coronagraph	Advanced Millimeter-Wave Focal-Plane Arrays for CMB Polarimetry		
Cryogenic Re	Detection Stabil	Tier 3 Technology Gaps	
Fast, Low-Noise	Heterodyne FIR	Advanced Cryocoolers	
Spectral Resolution	High-Efficiency	High-Performance	Tier 4 Technology Gaps
High-Efficiency	High-Performance	Large Cryogenic	Compact, Integrated Spectrometers for 100 to 1000 μm
High-Resolution	High-Reflectivity	Long-Wavelength	Optical-Blocking Filters
Large-Format	High-Throughput	Low-Noise, Fast	Rapid Readout Electronics for X-Ray Detectors
Large-Format	Large-Format Optics	Low-Stress, High	Short-Wave UV Coatings
Large-Format	Spectrometers for	Photon-Counting, Large-Format	Tier 5 Technology Gaps
Large-Format	Starshade Deployment	Polarization-Preserving Millimeter	Advancement of X-Ray Polarimeter Sensitivity
Next-Generation Spectrometers	Starshade Starlight	UV Coatings	Far-IR Spatio-Spectral Interferometry
Vis/NIR Detectors	Stellar Reflex Mission	UV Detection Sensitivity	High-Precision Low-Frequency Radio Spectrometers and Interferometers
	Stellar Reflex Mission	UV/Vis/NIR Tunable Narrow-Band	Mid-IR Coronagraph Contrast
		Warm Readout Electronics for	Ultra-High-Resolution Focusing X-Ray Observatory Telescope
			Very-Wide-Field Focusing Instrument for Time-Domain X-Ray Astronomy
			Wide-Bandwidth, High-Spectral-Dynamic-Range Receiving System for Low-Radio-Frequency Observations on the Lunar Far Side



PCOS Chief Scientist enables ground-breaking science from space by working at the interfaces between missions and studies, technology, the community, and NASA HQ.

Current PCOS Science Goals and Priorities:

- Ensure a more successful **Decadal survey** by supporting community preparations and HQ activities, spanning the range of inputs: from science to missions, technology, and state of the profession, which all impact our ability to do ground-breaking science
- Ensure more **successful missions** by
 - supporting ongoing mission studies and pre-projects, e.g., LISA, Lynx, Athena
 - through technology efforts, e.g., SAT;
 - by coordinating with current missions; and
 - by preparing for studies for mission recommended by the Astro2020 Decadal
- **Engage the community** to support a successful APD portfolio.



Keep up with the latest PCOS-related NASA News!

- PCOS-News emails
- Website: News & announcements

PCOS News

Program News and Announcements

16 December 2020

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4 December 2020

NICER seeks panel members for Cycle 3 proposal review » [Details](#).

4 December 2020

NASA Science seeking volunteer proposal reviewers in Earth and Space Science » [Details](#).

9 November 2020

SMD Community Town Hall on Tues 17 November to discuss updates to the Agency-wide science program. » [Details](#).

6 November 2020

NASA Fundamental Physics Program Virtual Town Hall on **3 December 2020**, to discuss research priorities in advance of the Biological and Physical Sciences Division Decadal Survey. » [Details](#).

5 November 2020

Call for proposals for Payloads and Research Investigations on the Surface of the Moon (PRISM). Step-1 Proposals are due **11 December 2020**. » [Details](#).



HEAD Newsletter

- PCOS News article
- Various SIG articles

The Gravitational Wave Science Interest Group

NICOLAS YUNES (UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN), JOHN W. CONKLIN (UNIVERSITY OF FLORIDA), KELLY HOLLEY-BOCKELMANN (VANDERBILT UNIVERSITY)

The **GW SIG** organized a Focus Session at the April APS Meeting 2019, which was held in Denver, Colorado. The speakers of the focus session were Nicolas Yunes from Montana State University (now at the University of Illinois Urbana-Champaign), Shane Larson (Northwestern University) and John Conklin (University of Florida). Dr. Yunes spoke about the science we expect to be able to extract with *LISA* in the future, with a focus on modified gravity and tests of General Relativity. Dr. Larson talked about "Adding *LISA* to your Toolbox", a summary of the broad *LISA* science case and tools to help interested researchers begin adding *LISA*-related calculations

Physics of the Cosmos News

T. J. BRANDT (NASA GSFC, PCOS CHIEF SCIENTIST), PANAYIOTIS TZANAVARIS (NASA/GSFC & CRESST), BERNARD KELLY (NASA/GSFC & CRESST)

NASA's **Physics of the Cosmos** (PCOS) program explores some of the most fundamental questions regarding the physical forces and laws of the universe: from testing General Relativity to better understanding the behavior of matter and energy in extreme environments; the cosmological parameters governing inflation and the evolution of the universe; and the nature of dark matter and dark energy. To enable current and future missions to address these questions, the PCOS Program Office (PO) engages with the community, executes the **Strategic Astrophysics Technology (SAT) program**, and facilitates formulation of new missions.

The PCOS Program Analysis Group (**PhysPAG**) includes everyone interested in the PCOS program via six Science Interest Groups (**SIGs**) and the **Multimessenger Astrophysics (MMA) Science Analysis Group (SAG)**; this probably means you! Other articles in this newsletter give updates on the activities of our SIGs, including **X-ray**, **Gamma-ray**, **Cosmic Ray**, and **Gravitational Wave** SIGs, and the **MMA SAG**. The PhysPAG provides fora for the PCOS community to regularly engage with the PO. PhysPAG **Executive Committee** (EC) members organize meetings, collect and summarize community input, and report to the Astrophysics Advisory Committee (**APAC**) and the

PhysPAG

Physics of the Cosmos Program Analysis Group

- Purpose:

- provide input to NASA relevant to PCOS
- help NASA inform interested parties about PCOS doings

- Membership: *You!*

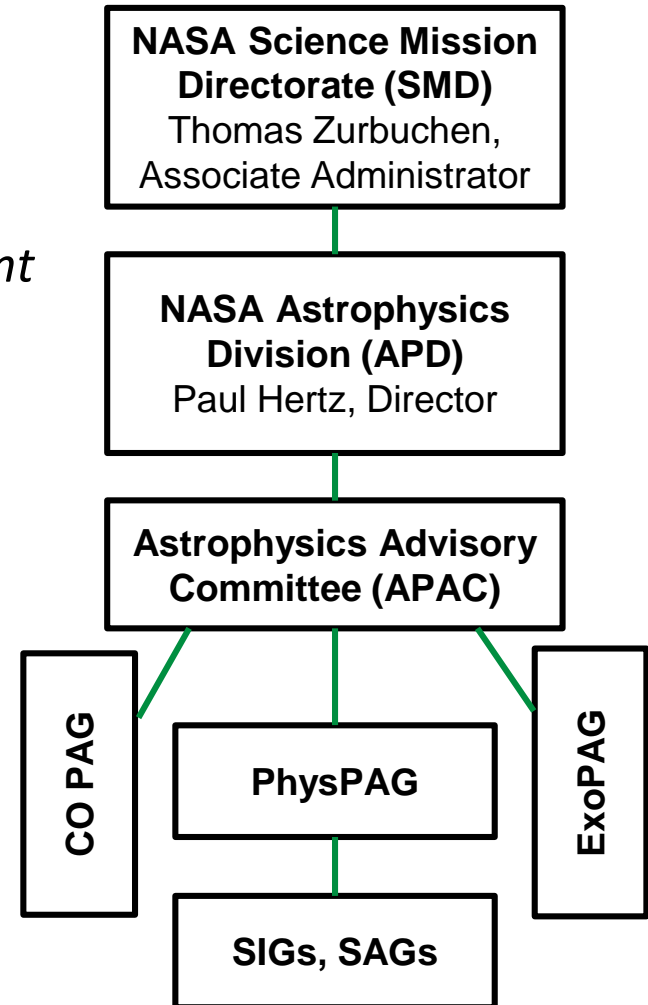
Anyone interested in providing input to NASA relevant to its Physics of the Cosmos Program

- Leadership:

- **Executive Committee (EC):**
 - Chair Emeritus: Graça Rocha
 - Chair: Ryan Hickox
 - Vice Chair: Grant Tremblay
- 11 EC members chair 6 Science Interest Groups (**SIGs**): longer-standing discipline-specific
- support formation of Science Analysis Groups (**SAGs**): group created to analyze a specific science question
- facilitate **info flow** between NASA and community

For more info: <https://pcos.gsfc.nasa.gov/phypag/phypag-ec.php>

Communication Network:



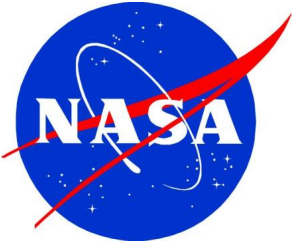
PhysPAG Science Interest Groups

- PhysPAG Executive Committee members chair 6 Science Interest Groups
 - **X-ray SIG** (XR SIG)
 - **Gamma-ray SIG** (GR SIG)
 - **Cosmic Ray SIG** (CR SIG)
 - **Gravitational Wave SIG** (GW SIG)
 - **Cosmic Structure SIG** (CoS SIG)
 - **Inflation Probe SIG** (IP SIG)
- SIGs serve as **forums for soliciting, discussing, and coordinating community input.**



We're listening!

For more info: <https://pcos.gsfc.nasa.gov/phypag/phypag-sigs.php>



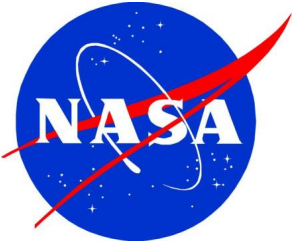
Let's Chat!



Sparks

- What have you found useful?
 - SIGs? SAGs?
 - professional exchange of ideas?
 - white paper preparations?
 - Strategic Astrophysics Technology (SAT) program?
 - ?
- What would you like to see more of ? or less of ?
 - more community leadership?
 - ?
- What do you need from NASA?
- What are you concerned about?

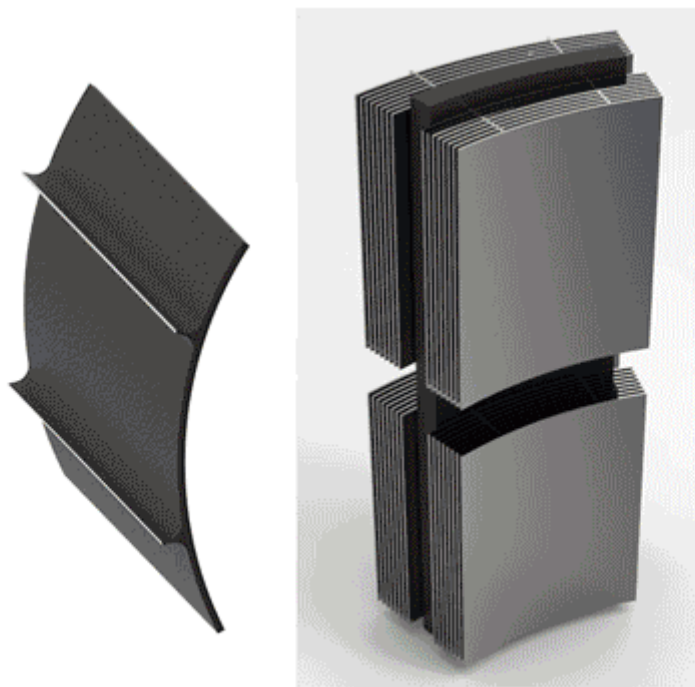




Conclusions

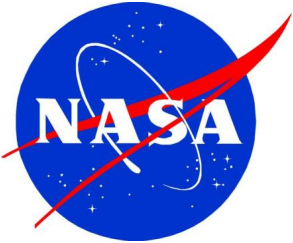


- PCOS will continue to work with the other program offices (COR, ExEP) to ensure that NASA is fully prepared for any recommendations made by the Astro2020 Decadal Survey
- PCOS will continue to provide insight and support for mission studies in development
- PCOS will continue to oversee the development of strategic technologies necessary for astrophysics in the coming years and decades
- PCOS, through the PhysPAG, will continue to offer scientific insight to NASA on various topics related to PCOS science



Single mirror segment plus stacked segments with support panel

PI: Zhang, William (GSFC)



Conclusions

AAS Sessions:

- Enhancing Participation of Minority Serving Institutions in Space Science (Monday, 6:50)
- Multi-SIG session on the status of multi-messenger astrophysics (Tuesday, 12:00)
- Inflation Probe SIG (Wednesday, 12:00)
- X-ray SIG (Wednesday, 6:50)
- Gravitational Wave SIG (Thursday, 12:00)
- Cosmic Structure SIG (Thursday, 4:10)

All times Eastern

Webinar Talks:

- Ryan Hickox, The First Black Holes (Wednesday, 12:30 – 1:00)
- Grant Tremblay, The Once and Future Great Observatories (Thursday, 2:00-2:30)

NASA Booth presence: Daily from 2:40-3:10

Sign up for our mailing list!

<https://pcos.gsfc.nasa.gov/pcosnews-mailing-list.php>